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NEW BRUNSWICK, NEW JERSEY, U. S. A.



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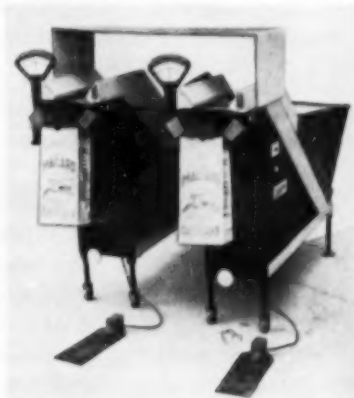
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OUR COVER PICTURE—Many potato growers find that the use of a potato harvester results in more efficient handling of the crop. The cost for harvesting is reduced compared with hand picking and loading. Photo courtesy Champion Corporation.

POTATO WART ERADICATION PROGRAM IN PENNSYLVANIA¹

R. E. HARTMAN²

Potato wart disease is caused by a fungus, *Synchytrium endobioticum*, which attacks the tubers and underground buds and stolons of potato plants. Such infected potatoes develop large wart-like growths, which may cover the entire tuber, making them useless for food.

Spores of this organism, when established in the soil, may remain alive for 20 or more years in the absence of host plants. This disease was prevalent in the principal potato growing countries of Europe and the British Isles for many years prior to its introduction into the United States, and considered a serious menace to the potato industry by British and European authorities.

Potato wart was introduced into this continent from Europe, probably on imported potatoes. It was found in Newfoundland in 1909 and is now known to occur in this country in Pennsylvania, Maryland and West Virginia.

Discovery of the disease in Pennsylvania was in the fall of 1918 (3). A state-wide survey made at that time and in later years, shows that the disease was confined to gardens in the anthracite and bituminous coal fields in the mountainous areas of eastern and central Pennsylvania. A total of 1,130 gardens scattered in 108 towns or villages located in 15 counties are now known to have produced potatoes infected with potato wart (Figure 1).

Soon after the discovery was made, a quarantine was established by the Pennsylvania Department of Agriculture, and regulations adopted to govern the growing of potatoes and the movement of all root crops and other materials in the infested areas. It was known that certain varieties of potatoes as grown in European countries were immune or resistant to the disease. These and later developed American immune varieties were the only ones permitted to be grown in the area where the disease was established.

Information essential for the control and eradication was obtained through biological studies of the wart organism; consideration of environmental conditions for wart establishment; testing the immunity or resistance of certain potato varieties; and the development of methods of soil sterilization.

POTATO WART

Symptoms—Potato wart is caused by a soil-borne organism of low type which attacks the tuber and underground parts of potato plants. These parts are not killed but the stimulation caused by the fungus results in the formation of small or large lumps of wart-like tissue about the eyes of the tuber, the general appearance of which suggests a cauliflower (Figure 2-A). In severe cases, this tumor development may be so pronounced that affected organs bear little resemblance to their normal forms.

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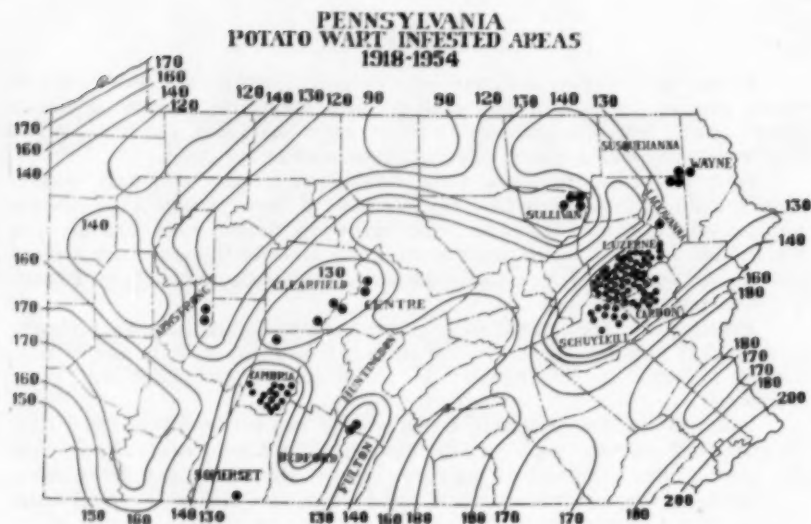


FIGURE 1.—Black dots show location of 108 infested towns and villages. Contour lines indicate length of growing season in days; i.e., 90 to 210.

In such extreme cases the stolon and buds involved may be little more than an irregular mass of meristematic and poorly differentiated parenchymatous cells with a few interspersed vascular elements (Figure 2-B). Millions of reproductive bodies, sporangia, are formed in the wart tissues and are released into the soil when the wart masses decay. These sporangia are of two types: one type germinates as soon as mature, releasing masses of zoospores which may infect the potatoes and cause new wart growths; the other type consists of resting spores which may lie dormant in the soil for many years, until by cultivation or other means they are brought into suitable conditions for germination. (Figures 2-A-B)

Method of Spread—Wart is spread by any means which would transport the organism. This would include the movement of table or seed potatoes, soil, vegetable waste, rooted susceptible plants, any plant with soil about the roots, and in manure. It might also be carried by vehicles and implements, flowing water, vegetable containers, or on the feet of man or animal. Wind is not an important factor in its dissemination.

WART IMMUNITY

The fact that certain varieties of potatoes remained entirely free from infection when grown in soils heavily infested with the wart organism has been known in Europe for a number of years and the cultivation of such resistant varieties was regarded there as the only practical means of control. Variety tests conducted in England had included several American varieties, and these were reported upon in 1919 (4). Aside from this, no information was available as to the reaction of American varieties to this disease.

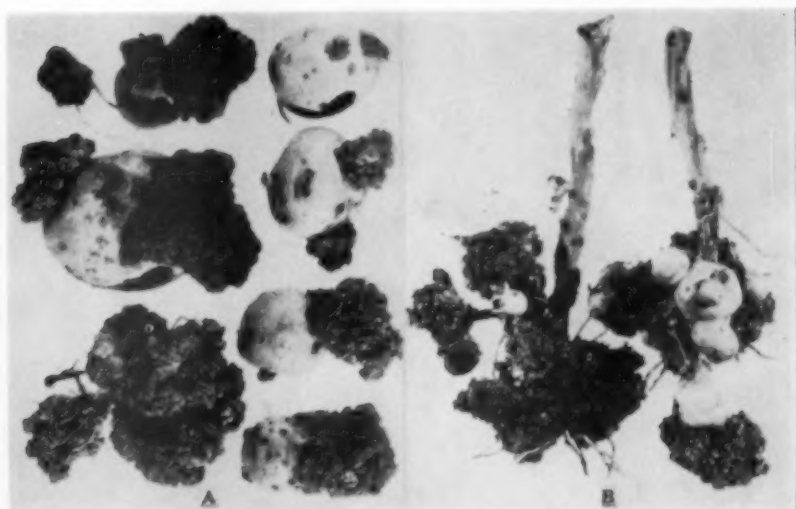


FIGURE 2.—A—Warted tubers. B—Warted stolon and stem buds.

In 1919 a systematic test of all available American varieties was begun. In addition, investigations of a number of immune English varieties were made to determine their reaction to wart in the United States. A preliminary report of these investigations was issued in 1920 (2), covering the results of the trials of the first season, followed in 1923 (5) by a detailed report of these investigations. These tests established the fact that the wart pathogen was consistent in its behavior in America and Europe. Immune European varieties also remained free from infection in this country. It was further shown that although most American varieties were susceptible, a few commercial varieties such as Irish Cobbler, Green Mountain and Spaulding Rose, were immune.

A limited program was continued for the purpose of testing all promising seedlings developed in the U.S.D.A. breeding program. These tests were made in heavily infested soils in the higher elevations of Pennsylvania. During the first years of these investigations, 1933 to 1940, to assure infection, the seed piece was dipped in warted soil inoculum or sprouted and exposed to live wart tissue and then incubated at temperatures of 56° to 58° F., for a period of 5 to 7 days prior to planting. Later, 1941 to 1954, immunity studies were made in the field in heavily wart-infested soils and found to be just as effective in determining wart immunity as the prior inoculation method (Figure 3, A & B).

A preliminary report covering these investigations was made in 1944 (1). This report and continued investigations show that a number of new seedling varieties are wart-immune. The most promising of these include: Katahdin, Sequoia, Ontario, Kennebec, Warba, Red Warba, Calrose, Pawnee and Chisago.



FIGURE 3.—Wart Immunity. A—Experimental plots, Drifton, Pa. B—Field plots, Bernice, Pa.

INFLUENCE OF SOIL TEMPERATURE AND RAINFALL

The wart disease has been found only in high altitudes where the climate is cool and moist. But distribution records indicate that the disease may have been very widely distributed throughout the Eastern States, because of the heavy importation of European potatoes prior to and including 1912, but has not persisted elsewhere.

Since wart is a soil-borne organism the influence of soil temperature and perhaps rainfall is believed to be the limiting factor in the establishment of infestations in this country.

Soil Temperature—Investigations were undertaken in 1927 to determine the influence of soil temperatures on wart infection and persistence. For this purpose, a battery of six soil temperature control units was used with a temperature range of 60° to 80° F. (Figure 4, A & B).

To determine the influence of soil temperatures on wart development, susceptible potatoes were grown in infected soils at temperatures of 64° - 66° - 68° - 70° - 72° - 74° F. These experiments were continued for five successive years with uniform findings. They show that wart infection occurs up to 70° F. with no infection at higher temperatures of 72° to 74° F. The optimum temperature for wart development is 62° to 64° F.

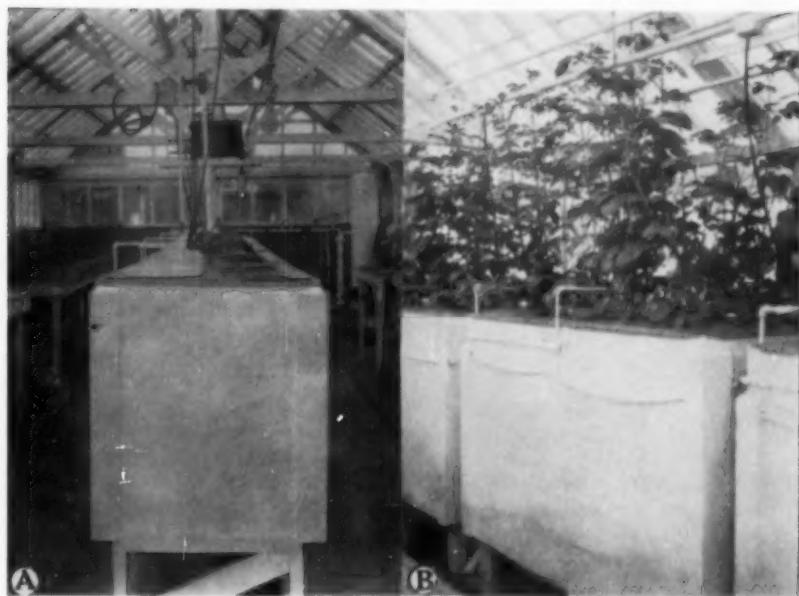


FIGURE 4.—Soil temperature control units. A—Battery of 6 independent units. B—Potato plantings.

Since soil temperatures influence the development of wart, it was planned to use the length of growing season — as determined by the number of frost-free days — as a basis for determining areas in which the mean soil temperature would favor or impede infection.

Climatological maps of Pennsylvania show a growing season range throughout the state of 90 to 210 days, divided into 10-day zones (Figure 1). The mean seasonal temperature of the soils at a depth of 6 inches was secured for each of these zones with soil thermographs. These records show that the mean soil temperatures in the various zones were as follows: 90 to 120 days, 60° - 63° F. — 120 to 130 days, 63° - 66° F. — 130 days to 140 days, 66° - 69° F. — 140 to 160 days, 69° - 72° F. — 160 to 180 days, 72° - 75° F.

The significance of soil temperature is apparent by noting that all wart infestations in Pennsylvania are located in the 120 to 130 day growing season zones, in which the seasonal mean soil temperatures are 63° to 66° F.

Rainfall—It was determined experimentally and by precipitation records that free soil moisture is essential for infection, but infection will also occur with periodic rains and is not necessarily tied up with a high total seasonal precipitation.

Longevity—A check planting of ten-year-old infested areas, which had been kept under continuous garden culture, but free from susceptible host plants, showed that wart had persisted in a small percentage of

infestation sites. Similar checks of areas kept in sod showed a 100 per cent infection.

Investigations were undertaken in 1928 to determine the longevity of resting spores in infested soils under varied culture or other conditions. For this purpose a suitable enclosure was built to assure complete isolation of the experiment (Figure 5 A). Five 100 ft. x 10 ft. concrete beds were constructed with each unit divided into 20 compartments of 50 sq. ft. area. The soils of each unit were uniformly infested by growing inoculated susceptible potatoes for one year, and then placed under one of the following cultural or artificial conditions: (1) Fallow, with periodic cultivation; (2) Sod; (3) Vegetables; (4) Immune potatoes; and (5) Soil covered with 8 inches of coal refuse (Figure 5 B).

In the first and succeeding years, one compartment of each unit was planted to 20 hills of susceptible Russet Rural potatoes. The first year of the experiment showed a uniform infection. By the fifth year a marked decrease in infection occurred under fallow and semi-fallow cultures, but the sod and coal-covered beds were 100 per cent infected. By the tenth year the fallow and wart immune potato units were free of infection, and the infection in the vegetable unit was less than 5 per cent. However, the sod and coal refuse units still were 100 per cent infected. At the end of the 15th year, the fallow, vegetable and wart immune units were wart-free, with the infection less than 10 per cent in the coal refuse and 50 per cent in the sod units. By the 20th year all units were free from the potato wart disease.

Results reported in this controlled experiment are similar to field observations. However, definite evidence is at hand which shows that potato wart has persisted in sods, abandoned gardens, and over-grown weed patches for 25 or more years and in one instance, 30 years.

WART ERADICATION

Soil Sterilization—Many materials and methods were tried and considerable information obtained (Figure 6, A & B). Heavy applications (2,500 to 3,000 pounds per acre) of ammonium thiocyanate; like amounts of copper sulphate; or 5 per cent solutions (20 gals. per 100 sq. ft.) of 40 per cent formaldehyde were found to kill all living forms of the organism.

The first successful eradication program got under way in 1932. For several years the operation was slow. Gardens were spaded, raked and then treated with an application of either ammonium thiocyanate or copper sulphate at the rate of 2,500 to 3,000 pounds to the acre. Either of these materials was mixed with moist sawdust, broadcast by hand over the surface, and worked into the soil with hand cultivators. In 1947 the eradication treatments were first made with the aid of power tools. Also high-gallonage power spray rigs were put to use.

WART ERADICATION PROCEDURE

The eradication procedure is as follows: The ground is cleared of all weed growth and rubbish. It is then plowed, harrowed, and the eradicant applied. The area is check-planted to susceptible potato varieties for a

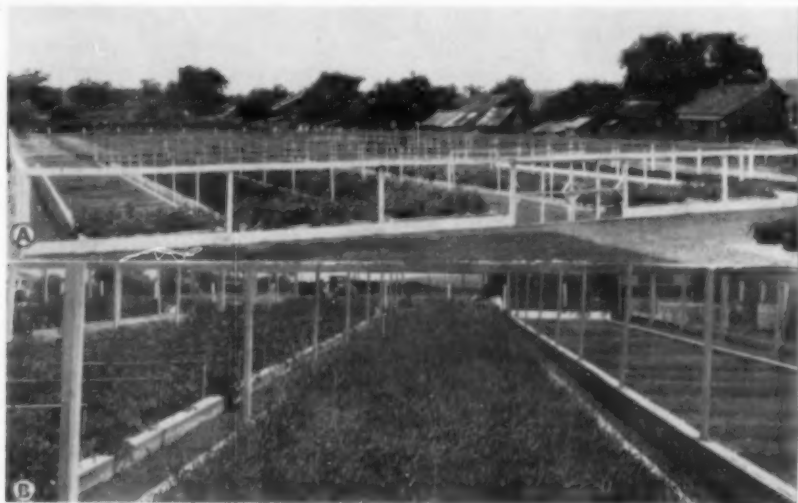


FIGURE 5.—Wart longevity plots. A—General enclosure. B—Individual cultural beds.

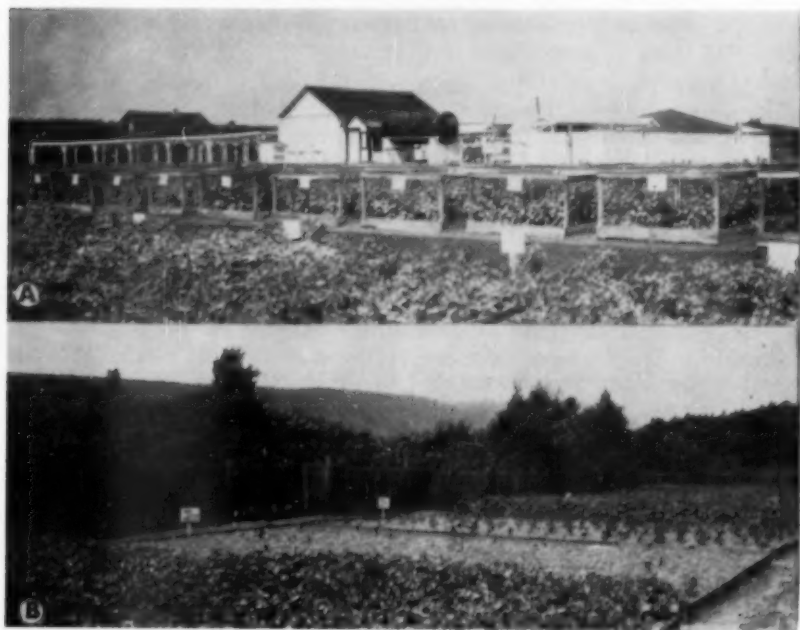


FIGURE 6.—Soil sterilization experimental plots. A—100 square feet experimental plots, Drifton, Pa. B—500 square feet field plots, Sanko's-Silver Brook, Pa.

period of four years. If no wart is found in these years, the ground is considered free from the wart organism.

Four methods are employed:

1. *Total Destruction*: Some land in the coal mining areas has been abandoned due to the closing of the mines. Such land usually belongs to coal companies. Eradication is accomplished by an application of 10,000 pounds of copper sulphate to the acre. Whenever practical, it is applied in the form of dry granules of copper sulphate. Areas such as those near foundations and sidewalks are treated with copper sulphate solution at the same 10,000-pound rate. No potato check-planting is used after this treatment. Eradication of the living wart organism has been completed in 216 gardens by this method.

2. *Standard Eradication*: This method is the one used on areas which are cultivated by the owners as vegetable gardens. There are three different applications with this method: (a) The portion of the plot in cultivation is treated with 2,500 to 3,000 pounds of copper sulphate to the acre, and then check-planted with a wart susceptible potato variety (Russet Rural) for four years; (b) the rough areas near walks and foundations are "totally destroyed" by fall treatment with 10,000 pounds of copper sulphate in solution to the acre; (c) lawns, flower beds, shrubs and trees are treated with 10 per cent solution of 40 per cent formaldehyde applied at the rate of 20 gallons to each 100 square feet. This method has been used to free 224 gardens from infestations, while 66 additional gardens of this type are chemically treated and undergoing check planting which follows treatment.

3. *Spot Treatment*: This method is followed in areas that were in continuous cultivation for 20 or more years, during which time potato planting was confined to immune varieties. The procedure for spot treatment is as follows: (a) The areas about borders, walks and drives are "totally destroyed" with 10,000 pounds of copper sulphate in solution to the acre; (b) lawns, flower beds, etc. are treated with formaldehyde solutions; (c) the untreated cultivated portion is check-planted with a susceptible variety for four consecutive years. In the fall the potatoes are dug and carefully inspected for the disease. An area of 25 square feet around each hill showing potato wart infection is treated with the 10 per cent formaldehyde solution at the rate of two gallons to each square foot. Should more than one per cent of the hills contain infected potatoes, the entire area is retreated by the standard or total eradication method. In all, 132 gardens have been found freed from potato wart by this method; 277 gardens are continuing under check-planting.

4. *Total Eradication*: This method is used in vegetable gardens in which the standard or spot treatment eradication method is not 100 per cent effective, also in all new infestations uncovered by surveys, to speed up wart eradication. (a) Cultivated portion of garden is planted to immune Cobblers for one season to assure decomposition of wart masses. (b) Immune Cobblers harvested in August, and cultivated areas treated with copper sulphate at the rate of 10,000 pounds per acre. This area is then kept fallow for one year with periodic disking. (c) After one year, treated areas are limed at the rate of 10,000 pounds per acre. (d) Six weeks after

liming these areas are seeded to a mixture of rye and grass seeds grown as a soiling crop until late the following spring, when the cultivated areas are plowed, disced, and planted to vegetables. This method has been used to eradicate the disease from 45 gardens.

Mining Activity a Help — The eradication program has been helped in several areas by surface mining of coal. In this type of mining, the surface soil is deeply buried under rock and coal refuse, with any seepage passing through heavily sulphured culm basins. The area is left rough and unfit for any near future cultivation. At least 165 gardens containing active wart growth have been destroyed in this manner.

Precaution in Eradication — The treating of lawns, landscaped areas and other prized plantings, and the application of the copper sulphate solution about walks and foundations, should be done in the fall after plant growth is killed by the frost. This greatly minimizes the damage which might be caused by the treatment materials.

Regardless of which method of eradication is used, it is very necessary to keep the equipment and personal attire free from the living wart organism, especially when going from one garden to another. A 10 per cent formaldehyde solution is used to clean all equipment and clothing. These precautions are necessarily followed through all parts of wart disease eradication.

Summary: The number of infestations eradicated under each of the above categories will be as follows: Mining Operations 165; Total Destruction 216; Spot Treatment 409; Total Eradication 50; Standard Eradication 290; for a total of 1,130 presently known infestations.

Chronological record of wart eradication.

<i>Known Infested Areas</i>	1932	1942	1947	1950	1954
Number of gardens	937	1073	1111	1113	1130
Number of towns or villages	100	108	108	108	108
Counties represented	12	15	15	15	15
<i>Infestations Eradicated</i>					
Gardens completely treated	0	229	375	440	782
Towns or villages completely treated	0	21	25	34	82
Counties completely treated	0	6	6	6	7
<i>Infestations Chemically Treated</i>					
Gardens treated and under check planting	0	42	49	333	348
<i>Infestations without Treatment</i>					
Number of gardens	937	804	736	340	NONE

CONCLUSIONS

1. A well enforced State quarantine has prevented spread of the potato wart disease from the original infested areas in Pennsylvania.
2. The early finding of immunity in American varieties and in many

of the developed seedlings, has provided a means of control.

3. The establishment of wart disease is limited to areas with cool, moist soils. There are, however, large areas in the United States with a climate similar to that of the infested areas of Pennsylvania.

4. Wart spreads slowly, usually by mechanical means or transportation of infected tubers, plants or soils.

5. The wart eradication effort in Pennsylvania is aimed toward complete eradication of the organism.

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STUDIES ON SUPPLEMENTAL IRRIGATION OF POTATOES
IN NEW JERSEY^{1,2}G. R. BLAKE, G. D. BRILL, AND J. C. CAMPBELL³

There is virtually unanimous agreement among research workers prior to 1920 that "frequent and light" irrigations are best for potatoes. "Frequent" and "light" are relative terms, however. In many of the researches the actual amount of water added was not known. A "light" application often meant approximately 3 inches and a heavy application varied from 7 to 9 inches. This was understandable with furrow irrigation methods where the amount added often depended on the permeability of the soil and the size of irrigation stream available.

With sprinklers there is need to determine more precisely the amount and frequency of irrigation most desirable for potatoes. The amount of water that can be added can be easily controlled by this method. The need for increased efficiency of irrigation also stems from the fact that the cost per inch of water is greater with sprinklers than with the furrow applications long used in the west. Even as a supplement to the 4 to 5-inch monthly average rainfall in New Jersey, often poorly distributed, irrigation is expensive. Under these circumstances it is important to use it to best advantage.

Two recent studies have been made by adding water at a time specified according to the dryness of the soil. Cyckler (2) in Wyoming grew potatoes in steel cylinders 1 foot in diameter and 30 inches deep. He added water to one group of cylinders when half of the available water was depleted. Moisture variation was at a minimum. He irrigated a second group when two-thirds of the available water was gone (medium moisture variation). A third group received water when 95 per cent was used (wide variation). He determined the moisture content by oven drying a soil sample. An amount of water necessary to bring the soil to field capacity was added at each irrigation. Relative yields were 100, 113, and 125 for the wide, medium, and minimum variations, respectively. These differences were significant. Cyckler extended these moisture levels to field plots and concluded that best results were obtained with a medium moisture level (3).

Jacob, *et al*, Long Island, New York (4) in a three-year supplemental irrigation study on potatoes added sufficient water to wet the top 12 inches of soil by sprinkling during one year and by flooding during two years. Their criteria for irrigating were tensiometer readings of 2.5, 5, 10, 20, and 40 inches of mercury. Tensiometers were placed at the six-inch depth. (They did not use all these levels every year.) This led to an average number of irrigations of 26, 14, 9, 5, and 3 per season, respectively. In this test they also had a non-irrigated series of plots. From their data they concluded that though optimum soil moisture might vary from year

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to year, it seemed to be "in the neighborhood of 20 to 40 inches of mercury tension," (0.67 to 1.33 atmospheres). Applications of approximately 1.5 to 2 inches of water per irrigation were necessary to wet the soil to 12 inches at these tensions.

DESCRIPTION OF EXPERIMENTS

1. *Variation of Irrigation Frequency and Amount*: Plots were set up in 1953 to study the optimum amount of water to add as supplemental irrigation on potatoes. Treatments consisted of applying water when tensiometers and gypsum blocks, buried at the 9-inch depth in potato rows, indicated that various amounts of the available water had been withdrawn by the crop. Tension levels of 0.8, 1.2 and 2.5 atmospheres were estimated to correspond in this soil to depletion levels of 33 per cent, 50 per cent, and 67 per cent of the available water, respectively. Potatoes have been found to obtain water to a depth of 22 inches in this soil as measured from the ridge top (1). Most of it is obtained from an even lesser depth.

The frequency of water application varied with the weather and particularly with the amounts of rain that occurred. Frequency did not change greatly during June and July. The time interval became a little greater during early August as vines began to mature.

Amounts of water per irrigation applied at the various depletion levels were 1 inch vs. an amount necessary to restore the available water reservoir. This depended on the depletion level but varied from 1 to 2 inches per irrigation. Treatments are summarized in table 1. Plots were randomized and treatments quadruplicated.

2. *Irrigation vs. No Irrigation*: Long-time effects of potato irrigation are reported from an experiment that has been in operation nine years. The treatments consisted of applying 1 inch of water when the tension at the 8-inch depth reached 1 atmosphere. This corresponds to approximately 40 to 50 per cent depletion of available moisture on this soil.

Both studies are located at the Vegetable Research Farm of the New Jersey Agricultural Experiment Station at New Brunswick. The soil is classified as Sassafras loam and is similar to a large part of the potato growing section of New Jersey. The potatoes used were the Katahdin variety grown in a two-year rotation with wheat seeded to clover. Experiment station recommendations on fertilizer rates and spray schedules were followed.

Water was applied by overhead sprinkling in both experiments. In the nine-year study rotary nozzles were used; in the study where amount and frequency were varied, a Skinner type system was manually changed in position to insure uniform distribution of the water on the plots.

RESULTS

Table 1 shows the results for 1953 and 1954 of adding different amounts of water at various soil moisture depletion levels. Yields were greatly increased in both years by all irrigation treatments. This amounted to an average increase of 41.3 per cent in 1953 and 70.5 per cent in 1954. It should be clearly understood that these years were severe drought years. As will be shown later, yield increases of this magnitude cannot be expected in New Jersey over a period of years.

TABLE 1.—*Effect of varying the application frequency and amount of water per irrigation on potato yields.*

Moisture Tension at 9" at Time of Application (Atmospheres)	Estimated Depletion of Available Water in Root Zone (Per cent)	Amount Water per Irrigation (Inches)	Time between Irrigations in Rainless Periods (Days)	Number of Irrigations in Season	Total Water Irrigation + Rain 5/15 to 9/1 (Inches)	Yields of U.S. #1 Bus./A.
1953						
No Irrigation	—	—	—	0	10.2	290.6
0.8	33	1.0	5.5	6	15.2	403.8
1.2	50	1.0	5.5	5	14.2	405.4
1.2	50	1.5	8	4	15.2	433.0
2.5	67	1.0	6	4	13.2	399.9
2.5	67	2.0	10	4	17.2	410.9
1954						
No Irrigation	—	—	—	0	14.0	292.2
0.8	33	1.0	6	8	22.0	514.6
1.2	50	1.0	6	7	21.0	512.7
1.2	50	1.5	9	5	21.5	483.9
2.5	67	1.0	6	6	20.0	480.9
2.5	67	2.0	12	4	22.0	498.9

L.S.D., (Yields (Bus./A.))	1953	1954
	.05 34.1 .01 47.1	43.7 60.4

Yield differences between the various irrigation treatments were not significant at the 5 per cent level. Nevertheless, there is a trend, consistent in both years, for yields to be lower where one inch of water was added at the 67 per cent depletion level. It is possible that a 1.5 or 2-inch application would require less labor in moving pipe than the more frequent application of 1 inch. This suggests that applications of 1.5 to 2 inches might be preferable to 1 inch in dry years. Even in relatively wet years the greater amounts with less frequent applications would probably lead to less unnecessary irrigation (irrigation followed by rain) than 1 inch each 6 days. These conclusions are based on two dry years. It is possible that other significant effects will be noted in those years in which rainfall amount and distribution are more desirable. These studies are continuing so that such observations can be made.

Though table 1 shows that rain plus irrigation was greater in 1954 than 1953, much of that in 1954 fell during the middle and latter part of August when the vines were nearly mature. During June and July when the vines were in their most active growth stages there was less water, as rain, in 1954 than in 1953, as shown in table 2.

As was indicated in table 1, yield increases from irrigation were great in 1953 and 1954, since these were dry years. The increases obtained over the nine-year period from 1946 through 1954 are shown from results of the other experiments already described, at the Vegetable Research Farm in New Brunswick. (Table 3.) Yield increases were obtained every

TABLE 2.—Rainfall by months at New Brunswick, N. J., in 1953 and 1954.

Month	Rainfall in Inches		
	1953	1954	40-Year Average
May.....	4.3	3.7	3.6
June.....	3.2	2.0	3.8
July.....	2.6	1.5	5.1
August.....	2.6	7.6	5.2

TABLE 3.—Effect of supplemental irrigation on potato yields, 1946-1954.

Year	Yields U. S. No. 1 Bus./A.		Increase from Irrigating	
	Not Irrigated	Irrigated	Bus.	Per cent
1946.....	217	250	33	15
1947.....	331	346	15	5
1948.....	*	*	*	*
1949.....	121	352	231	191
1950.....	309	334	25	8
1951.....	324	429	105	32
1952.....	227	262	35	15
1953.....	220	358	138	63
1954.....	193	421	228	118

*Only 1 irrigation was necessary in 1948 and this was followed by rain within 24 hours. Yield differences not taken but assumed to be nearly zero.

year. In many years, however, the increase was small. In 1949, 1951, 1953, and 1954 the yields were substantially increased by irrigation. Eighty seven per cent of the nine-year yield increase from irrigation was obtained during these four years.

DISCUSSION AND SUMMARY

The data indicate that potato yields on Sassafras loam were equally good when available soil moisture was depleted between 33 and 67 per cent before irrigation. There was a tendency for an amount greater than 1 inch to be the best application where the soil was allowed to dry to the higher depletion level. The results are in agreement with those of Jacob, *et al* (4) that applications of 1.5 to 2 inches every 10 to 12 days in rainless periods in mid-summer were adequate on this soil. This frequency and amount would probably also be most economical of labor in moving pipe.

In those cases where a farmer must begin irrigating a crop before the 67 per cent depletion level is reached, to insure getting over his acreage, it may be that on the first settings there will be a soil moisture deficit of only an inch. As the rainless period lengthens and part of the acreage is covered, a 1.5 to 2-inch application may be made on loam soils with a consequent lengthening of the interval between irrigations.

In some years yield increases from irrigation were small. This lack of response to irrigation occurred when rainfall was well distributed. Even in those years, however, from 1 to 5 irrigations were made. Often they were followed by rain. It is doubtful that the yield increases in those years were sufficient to offset the cost of irrigation. In other years irrigation gave large increases in yield. Since neither the wet year nor the drought year can be predicted, irrigation is a means of assuring high yields in dry years. Costs of irrigating potatoes in New Jersey vary greatly, depending on the cost of developing a source of water and other factors. The questions of actual costs and economic returns are beyond the scope of this paper.

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THE WEIGHT OF POTATOES IN WATER¹M. NISSEN²

INTRODUCTION

The content of dry matter in potatoes may vary considerably, and a method for estimating quality in potatoes for industrial use is therefore necessary. For routine purposes it is customary to weigh a 5-kg sample of potatoes in water and to find the percentages of starch and of dry matter by means of a table. Several tables have been constructed for this purpose. The most commonly used is that of Maercker, (2) which like most others (3-4-6) rests on the assumption that the percentage of dry matter (y) is a linear function of the specific gravity (V) of the potato tubers, according to the equation:

$$y = 214 (V - 0.988).$$

This assumption is only justified if the specific gravity of the dry matter (v) is a variable. If v is a constant, y becomes a linear function of the weight of the potatoes in water (x). The specific gravity of the potato tubers (V) depends on the weight of a 100-gm sample in water,

according to the hyperbolic function $V = \frac{100}{100 - x}$, $x = 100 - \frac{100}{V}$

while the dry matter percentage depends on the weight of potatoes in water (x) according to the linear function

$$y = bx + k.$$

The constant k must be added to the value found by multiplying the weight in water (x) by the regression coefficient (b), because the determination of the weight in water is subject to an error caused by the air content of the potato tubers.

Despite the fact that V is a hyperbolic function of y (this being a linear function of x), the specific gravity of the potato tubers, it may yet serve as a basis for constructing tables of dry matter percentages, owing to two circumstances. Firstly, the curve representing V in relation to y only departs slightly from linearity within the section of the curve that comes into consideration when potatoes are weighed in water, and secondly a constant is subtracted from V . In Maercker's table, for instance, the value of 0.988 is subtracted, which makes the table conform reasonably well to the observed data. The agreement between percentages of dry matter found by means of Maercker's table and by oven-drying is often unsatisfactory. The problem has therefore been subject to a closer investigation.

EXPERIMENTAL

The samples of potatoes were obtained partly from field experiments at this station, and partly from experiments conducted by the potato

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³Investigations on the relation between dry matter and starch content of potatoes and their weight in water, with or without air evacuation.

starch factories. Observations on the weight of 5-kg samples in water were commenced in 1937. After weighing and superficial drying, one quarter of each tuber in the sample was grated finely, and dry matter was determined by oven-drying of approximately 10 grams of pulp in a small glass beaker for 24 hours at 90° C. The content of dry matter was found to vary between 17.36 and 33.01 per cent. A calculation of correlation according to the method of least squares (5) in 1911 samples examined between 1937 and 1948 showed:

$$b = \frac{\sum dx \, dy}{\sum dx^2} = 0.0500 \pm 0.0005.$$

$$k = G_y - G_x b = 2.00. \quad (G_y \text{ and } G_x \text{ denoting means of } y \text{ and } x).$$

The formula $y = bx + k$ for calculating the percentage of dry matter on the basis of the weight of 5 kgs. potatoes in water thus becomes:

$$y = 0.05x + 2.00.$$

When this formula is used, the results often differ considerably from those found by oven-drying. The difference has often exceeded one unit of dry matter percentage (from + 1.19 to - 1.51) during the years 1947-1952.

The Air Content of Potatoes. The large differences shown by the two methods must be largely ascribed to a varying content of air in the potato tubers (1), which causes a certain buoyancy during the weighing in water. Further tests were therefore from 1948 to 1951 made on 266 samples in which the weight in water was also determined after removal of air from the tubers. In addition, the content of starch was determined by the method of Ewers. Weighing in water and oven-drying were performed as before, and further weight of potatoes in water was determined by weighing approximately 20 grams of potato pulp in a Rapp-Degener flask after evacuation of the air from the pulp. Before the determinations the pulp was usually preserved by the addition of 0.5 per cent benzoic acid and 1.0 per cent concentrated hydrochloric acid. The addition of acid facilitates the removal of air but renders a correction necessary.

A small volume of water was added to the pulp in the flasks, before these were placed in the vacuum desiccator. Suction was applied until the foam rose into the neck of the flasks, a suitable volume of air was then passed into the desiccator, and this operation was repeated until all air had been removed from the pulp. In this way the weight of a 5-kg sample of potatoes in water may be determined quite accurately, the mean error amounting to approximately 0.5 per cent (mean error $m^2 =$

$\frac{[d^2]}{2p}$, d representing the difference between duplicate determinations, and p the number of samples tested).

The weight of potatoes in water usually increases somewhat by the vacuum treatment; the increase may be considered to equal the buoyancy caused by the acid content of the potatoes. This buoyancy averaged 27 grams per 5 kilograms in the 266 samples, but varied greatly in individual samples from zero to 63 grams per 5 kilogram, these figures pertaining to the samples that showed 1.19 per cent more and 1.51 per cent less

dry matter, respectively, by weighing in water than by oven-drying. As a rule there was a satisfactory agreement between the air content of the potatoes and the differences in dry matter found by the two methods (oven-drying and weighing in water). The widely divergent results found by the use of table in the earlier tests suggested, are probably because of the construction of these tables on the basis of an insufficient number of determinations, and therefore the tables become biased by the air content of the potatoes. One might expect to be able to find the dry matter percentage of air-free potatoes by the use of the formula

$$y = 0.05 x,$$

since k should equal the buoyancy caused by the air. The calculated value of k in 1911 samples (1937-1948) was 2.00, whereas the buoyancy directly determined was 30 grams/5 kilograms which corresponds to 1.50 per cent matter if $b = 0.05$. A residual value 0.50 thus remains, and for dry matter in air-free potatoes we thus have the formula

$$y = 0.05 x + 0.50.$$

Continued drying of the pulp for more than 24 hours at 90° C. resulted in a loss of weight; after 72 hours the percentage of dry matter was approximately 0.25 per cent lower than after 24 hours. If we assume the observed percentage of dry matter to be too high by 0.25, there still remains a residual k -value of 0.25, the origin of which is not readily explicable. Determinations of the specific gravity of potato dry matter, however, suggests that the observed value of $b = 0.05$ is slightly too low and should correctly be 0.0505. If this value is used, the figures expressing the mean dry matter percentage ($G_y = 23.85$) and mean weight in water ($G_x = 466$) the 266 samples will approximately, without any correction for k , fit the equation $y = b x$, as we then have: $23.85 - 0.32 = 466 \cdot 0.0505$. This implies that the dry matter still contains 0.32 per cent water after drying for 24 hours.

The Specific Gravity of Potato Dry Matter. The regression coefficient b may be calculated according to the formula

$$b = \frac{v}{v - 1}$$

(where v denotes the specific gravity of the dry matter), since one cubic centimeter of dry matter loses one gram in weight by immersion in water. If $v = 1.666$, $b = 0.05$, and if, for instance, the percentage of dry matter is as low as 16.66, the dry matter in 100 grams of potatoes will weigh 16.66 grams, its volume will be 10 cubic centimeters, and the weight of the potatoes in water will be $16.66 - 10.00 = 6.66$ grams. The proportion between the weight of dry matter in 100 gm potato material (y) and the weight of the same sample in water (x) becomes $16.66/6.66 = 2.5$, which is the value of b for a 100-gram sample; 5-kilogram samples then gives us: $b = 2.5/50 = 0.05$. In practice, samples of 5 kilograms are generally used. It is assumed that, firstly, the water in the potatoes, and the water in which they are weighed have a specific gravity of one; and, secondly, the weight of the potatoes in water depends only on the content of dry matter but not on the water content. Nothing in the present investigations indicates that this theory is incorrect.

In dry pulp from 26 samples examined in 1952 the specific gravity of dry matter was determined by placing a weighed sample of air-dry material in a pycnometer, whereas the dry matter was determined in another sample. The material in the pycnometers was freed of air by vacuum treatment, and its weight in water was determined next. The specific gravity of the dry matter was found to vary between 1.6537 and 1.6811, with a mean of 1.6689. These figures correspond to *b*-values of 0.0506, 0.0494, and 0.0499, respectively.

The samples for determination of dry matter were dried very vigorously in a large oven with circulating atmosphere, in order to remove all moisture from the material. Constant weight proved difficult to obtain, for which reason the temperature was raised to 120° towards the end of the drying period. Tentative observations in 1953 on the influence of drying on the specific gravity of the dry matter showed that the weight of the dry matter in 5 grams of air-dry material decreased by vigorous drying. Therefore, some substance of a specific gravity different from that of water disappears during the drying.

The determinations of the weight of dry matter in water show a good agreement between duplicate samples, the standard error ($m^2 =$

$\frac{[d^2]}{2p}$) amounting to ± 0.054 per cent. Calculation on the basis of the

samples analyzed shows a dry matter content of 88.85 ± 0.07 per cent. Thus, if the exact value of *v*, the specific gravity of the dry matter, is known, the weight of the substance in water permits a fairly reliable estimation of its dry matter percentage, according to the formula:

$$y = \frac{xv}{v-1} = bx.$$

The stage of drying when all water has evaporated and dry matter begins to disappear, is not easily defined. Six samples of air-dry potato material were heated for 5 hours at 103° C. in a large oven with circulating atmosphere; a mean dry matter content of 88.42 per cent was found. If we call the weight of the sample of air-dry material *a* and its content of dry matter *A*, then $A = ay/100$, or, $A = 88.42 a/100$. Further, since $v = A/A-x$, we find that $v = 1.6594$. The samples were dried for another 48 hours at a somewhat higher temperature, for the last 16 hours at 125°C. The percentage of dry matter was now 87.37, which gives us: $A = 87.37 a/100$, and $v = 1.6728$. On transfer to a pycnometer, 5 gms. (a) of the sharply dried material showed a weight in water (*x*) of 1.732 gms., against 1.757 gms. before drying. Inserting $x = 1.732$ in the formula $A/A - x$, we find that $v = 1.6569$. This suggests that all water had evaporated after 5 hours at 103°C., and that 1.6594 is a more nearly correct value of *v* than 1.6728. The figure 1.6689, estimated on the basis of 26 samples in 1952, is therefore probably also too high. The most recent observations suggest that values of $v = 1.655$ and $b = 0.0505$ are approximately correct. The investigations, however, should be continued. Drying of the material in the pycnometers would be preferable. There is no guarantee that the specific gravity of the dry matter is constant; it may vary slightly according to the variety of potato or the conditions of growth.

Additional experiments have shown that a really exact determination of dry matter is difficult to achieve, because the loss of weight in drying depends not only on time and temperature, but also to a great extent on the type of oven and especially on the circulation of the oven atmosphere. The most accurate results seem to be obtained by weighing a sample of air-dry material in water and multiplying the weight of 5 kilograms by 0.0505. The six above-mentioned samples showed, by this method, a content of 88.73 per cent dry matter, but 88.42 per cent by oven-drying for 5 hours at 103°C which suggests that some dry matter was lost.

Evacuation of Air from Whole Potatoes. Evacuation of air from potato pulp in a flask is cumbersome and not convenient except in laboratory work, but it has been found possible to remove the air from whole potato tubers by keeping them immersed for 30 minutes in a container where the air pressure is reduced to 10-30 millimeters of mercury. After vacuum treatment, the potatoes are left in the water for 10 minutes at atmospheric pressure. All samples must be weighed before the vacuum treatment, which causes an increase in their weight (the removed air being replaced by water), and the vacuum treatment must take place without interruption. Potatoes treated in this manner decay very quickly.

Starch Content. Determination of starch in 266 samples by the method of Ewers showed that the mean starch percentage is approximately 5.2 lower than that of dry matter. The difference, however, increases with the content of dry matter, being 4.8 when $x = 260$, but 5.6 when $x = 600$ gm. The starch content cannot, on the basis of the weight of the potatoes in water, be determined as accurately as that of dry matter.

The Accuracy of Dry Matter Determination by Different Methods. Dry matter and starch were determined in 23 potato samples by different methods. The weight of 5 kilograms of potatoes in water was determined (a) by weighing the untreated, (b) the vacuum-treated potato tubers in water, and (c) by weighing the vacuum-treated pulp in a 100 milliliter measuring flask. Further, the pulp was oven-dried for 24 hours at 90°C, and starch was determined by the method of Ewers. Percentages of dry matter and starch were calculated according to the above-mentioned formulas, and also from the tables of Maercker, Behrend and Morgen. Standard deviations were calculated according to the formula

$$S.D. = \frac{\sqrt{[d^2]}}{n}$$

where d indicates the difference between percentage of dry matter found by oven-drying and by other methods, or between percentage of starch according to Ewers and according to other methods; n indicates the number of samples.

Table 1 shows that the figures found at this Station give a considerably greater accuracy in dry matter and starch determinations than Maercker's table. The accuracy is further increased if air is removed from the potatoes before the determination of the weight in water. It must be remembered that the determinations of dry matter by oven-drying and of starch by Ewer's method are both subject to errors that influence the standard deviation. When $S.D. = \pm 0.34$ in air-free tubers but only ± 0.18 in

TABLE 1.—*Standard deviations of different methods.*

	Mean Per cent	S. D. \pm Per cent
Weight of untreated potatoes in water (Per cent dry matter according to Maercker's table)	23.34	0.87
Per cent calculated from $y = 0.05 x + 2.00$	24.10	0.55
Weight of air-free potatoes in water (Per cent dry matter calculated from $y = 0.05 x + 0.5$)		
Per cent vacuum-treated tubers	23.76	0.34
Per cent vacuum-treated pulp in flasks	23.76	0.18
Weight of untreated potatoes in water		
Per cent starch according to Maercker's table	17.59	1.18
Per cent starch from $y = 0.0478 x - 2.28$	18.85	0.56
Weight of air-free potatoes in water, determined in pulp:		
Per cent starch calculated from $y = 0.0478 x - 3.72$	18.52	0.39

air-free pulp, the difference may be due to the fact that the pulp used for the determination of weight in water is taken from the same sample as the pulp used in oven-drying: cutting and pulping of the tubers involve sources of error, and the higher standard deviation in air-free potatoes may possibly be due to these errors. If the deviations of the two methods could be compared with a dry matter determination theoretically free from errors, both methods might show approximately the same deviation.

A Table for Finding Percentages of Dry Matter and Starch. Our experiments have shown that the percentage of dry matter in potatoes increases by 0.05 when the weight in water increases by 1 gram per 5 kilograms. A zero weight in water must be assumed to correspond to 2.00 per cent dry matter. The following equations apply to untreated potatoes:

$$\text{Per cent dry matter: } y = 0.0500 x + 2.00$$

$$\text{Per cent starch: } y = 0.0478 x - 2.28$$

Correspondingly we have for air-free potatoes:

$$\text{Per cent dry matter: } y = 0.0500 x + 0.50$$

$$\text{Per cent starch: } y = 0.0478 x - 3.72$$

Table 2 shows the percentages of dry matter and of starch, calculated from these formulas and based on the weight of 5 kilograms of potatoes in water, varying at 5 gram-intervals between 260 and 600 grams.

TABLE 2.—Percentages of dry matter and starch for *x* gramme weight of 5 kg potatoes in water.

Weight in Water Gms. (x)	Vacuum-treated		Not Vacuum-treated		Weight in Water Gms. (x)	Vacuum-treated		Vacuum-treated Not	
	Dry Matter Per cent	Starch Per cent	Dry Matter Per cent	Starch Per cent		Dry Matter Per cent	Starch Per cent	Dry Matter Per cent	Starch Per cent
260	13.50	8.71	15.00	10.15	435	22.25	17.07	23.75	18.51
265	13.75	8.95	15.25	10.39	440	22.50	17.31	24.00	18.75
270	14.00	9.19	15.50	10.63	445	22.75	17.55	24.25	18.99
275	14.25	9.43	15.75	10.87	450	23.00	17.79	24.50	19.23
280	14.50	9.66	16.00	11.10	455	23.25	18.03	24.75	19.47
285	14.75	9.90	16.25	11.34	460	23.50	18.27	25.00	19.71
290	15.00	10.14	16.50	11.58	465	23.75	18.51	25.25	19.95
395	15.25	10.38	16.75	11.82	470	24.00	18.75	25.50	20.18
300	15.50	10.62	17.00	12.06	475	24.25	18.99	25.75	20.43
305	15.75	10.86	17.25	12.30	480	24.50	19.22	26.00	20.66
310	16.00	11.10	17.50	12.54	485	24.75	19.46	26.25	20.90
315	16.25	11.34	17.75	12.78	490	25.00	19.70	26.50	21.14
320	16.50	11.58	18.00	13.02	495	25.25	19.94	26.75	21.38
325	16.75	11.82	18.25	13.26	500	25.50	20.18	27.00	21.62
330	17.00	12.05	18.50	13.49	505	25.75	20.42	27.25	21.86
335	17.25	12.29	18.75	13.73	510	26.00	20.66	27.50	22.10
340	17.50	12.53	19.00	13.97	515	26.25	20.90	27.75	22.34
345	17.75	12.77	19.25	14.21	520	26.50	21.14	28.00	22.58
350	18.00	13.01	19.50	14.45	525	26.75	21.38	28.25	22.82
355	18.25	13.25	19.75	14.69	530	27.00	21.61	28.50	23.05
360	18.50	13.49	20.00	14.93	535	27.25	21.85	28.75	23.29
365	18.75	13.73	20.25	15.17	540	27.50	22.09	29.00	23.53
370	19.00	13.97	20.50	15.41	545	27.75	22.33	29.25	23.77
375	19.25	14.21	20.75	15.65	550	28.00	22.57	29.50	24.01
380	19.50	14.44	21.00	15.88	555	28.25	22.81	29.75	24.25
385	19.75	14.68	21.25	16.12	560	28.50	23.05	30.00	24.49
390	20.00	14.92	21.50	16.36	565	28.75	23.29	30.25	24.73
395	20.25	15.16	21.75	16.60	570	29.00	23.53	30.50	24.97
400	20.50	15.40	22.00	16.84	575	29.25	23.77	30.75	25.21
405	20.75	15.64	22.25	17.08	580	29.50	24.00	31.00	25.44
410	21.00	15.88	22.50	17.32	585	29.75	24.24	31.25	25.68
415	21.25	16.12	22.75	17.56	590	30.00	24.48	31.50	25.92
420	21.50	16.36	23.00	17.80	595	30.25	24.72	31.75	26.16
425	21.75	16.60	23.25	18.04	600	30.50	24.96	32.00	26.40
430	22.00	16.83	23.50	18.27					

SUMMARY

Approximately 2000 samples of potatoes have been examined in order to evaluate the different methods suggested for routine determination of dry matter and starch. Comparisons between the weight of 5-kilogram samples of potatoes in water and the percentage of dry matter found by oven-drying of pulp from the same samples showed that the average weight of 5 kilograms of potatoes in water multiplied by a regression coefficient (b) of 0.05 equals the percentage of dry matter minus 2.00. It was later found possible to calculate b from the equation

$$b = \frac{v}{v - 1}.$$

where v denotes the specific gravity of the dry matter; this way of calculation is probably the most exact as well as the most convenient.

Potatoes have a strongly varying content of air that causes a certain buoyancy during weighing in water. Largely owing to this buoyancy the percentage of dry matter is found approximately two units too low if calculated by multiplying the weight in water by b . The air may be removed by keeping the potato sample immersed in water for one-half hour under vacuum.

Dry matter in potatoes may then be determined by three methods: (a) by oven-drying the pulp, (b) weighing a 5-kilogram sample of untreated tubers in water, and (c) by similar weighing after evacuation of air from the potatoes. Oven-drying may yield reliable results, but is rather laborious. Weighing in water is therefore usually preferred as a routine method, and the data given in table 2 permit a more accurate determination of dry matter than does Maercker's table. To obtain exact results it is, however, necessary to remove the air from the potato tubers before weighing in water; this may be done without too great inconvenience if a suitable number of samples are vacuum-treated simultaneously.

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EFFICIENCY OF VARIOUS METHODS OF WASHING
RED RIVER VALLEY POTATOES¹J. M. LUTZ, HERBERT FINDLEN AND JOHN HANSEN²

INTRODUCTION

Red River Valley table stock potatoes usually cannot be marketed successfully unless they are washed. They are grown mostly on the Fargo silty clay and the somewhat lighter Bearden soils. Although these latter soils are somewhat lighter than the Fargo clay, which lies in the lower part of the Valley along the Red River, they are, as a rule, very sticky and easily compacted when wet. When potatoes are harvested from Bearden soils high in moisture content, the soil compacts on the tubers, become very hard, and adhere firmly when dry. Such was the case in 1951, when rainfall was much above normal just prior to harvest. Rainfall recorded at Grand Forks, North Dakota, in August was 7.90 inches (5.28 inches above normal), of which 3.85 inches fell on August 30. The September rainfall was only 1.12 inches (0.80 inch below normal) but the soil contained sufficient moisture to be easily compacted at harvest time. Many tubers resembled balls of mud and, even after washing in conventional washers, some of them were still badly caked with compacted soil. Since the Valley soils are dark grey (when dry) and black (when wet), a little soil adhering to the potatoes materially detracts from their appearance. The experiments reported here were conducted to develop satisfactory methods of washing potatoes coated with adhering soil.

MATERIALS AND METHODS

The potatoes used in 1951 were from the late crop and had been in storage for at least a month. The individual potatoes selected for the tests had a heavy coating of soil. The percentage of the potato surface still covered with soil after washing was calculated from estimates made on each individual potato in the lot. The potatoes used in 1952 were relatively free from adhering soil, and since they had been stored less than a month, they were relatively turgid. They were used only to determine the effect of the washing equipment on potatoes. The bruising index was determined by a method previously described. (2)

One washer used in these tests was a transverse-roll, or brush, washer made up of nine pintle (soft round rubber fingers $\frac{1}{2}$ inch in length), rubber-covered steel rolls 36 inches long, five of which are $4\frac{1}{2}$ inches in over-all diameter and four $5\frac{1}{2}$ inches in diameter. The rolls are spaced parallel $5\frac{1}{2}$ inches on center. The pintles are spaced $7/16$ inches apart in rows $9/16$ inches apart, arranged in a spiral pattern around the rolls. Water is continually sprayed on the potatoes from above by eighteen 65° flat-spray nozzles (Veejet $\frac{1}{8}$ U 6530) as they pass from one brush to the next. The amount of water used is calculated as 54 gal./min. at 40-pounds pressure.

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The other washer was a tumbler, or rotary-drum, washer which consisted of a slatted cylinder 7 feet in length and 3 feet in diameter, rotating on an axis substantially in a horizontal plane in a tank partially filled with water as shown in figure 1. The intake end of the cylinder is 2 inches higher than the outlet. The tank was partly filled with water, to a depth of 12 inches above the bottom part of the drum. In operation, the peripheral speed of the drum is 1 mile per hour. The working load was approximately 400 pounds of potatoes, which were about 80 per cent submerged while the drum was rotating. The washing action was accomplished largely by the potatoes rubbing against one another; the amount of rubbing was regulated by adjusting the height of the gate over which the potatoes emerged from the washer and by the depth of the water in the tank.

RESULTS

Effect of Presoaking

As shown in table 1 and figure 2, presoaking in water prior to washing was very effective in facilitating removal of soil. A 5-minute presoaking period reduced the soil remaining on the potatoes to an average of less than $\frac{1}{2}$ that on potatoes not presoaked and a 15-minute presoaking period reduced it to nearly $\frac{1}{6}$. Longer presoaking periods further reduced the amount of soil remaining. These results show that, in commercial practice, soaking the potatoes in a tank of ample capacity in the line ahead of the washer is an effective method of increasing the efficiency of washing. It is probably desirable in designing a tank to make sure that the water is not more than 5 feet above the lowest potatoes because of the danger of hydrostatic pressure forcing moisture and bacteria into the lenticels and causing infection by decay organisms. (1)

Fluming potatoes from the bins to the washer aids slightly in soil removal as it provides the equivalent of a short presoaking period.

TABLE 1.—*Relation of soil remaining on potatoes to lengths of presoaking periods and washing periods in a brush washer.*

Presoaking Period	Surface Covered with Soil after Indicated Washing Period ¹			
	$\frac{1}{2}$ Minute	1 Minute	1½ Minutes	Average
	Per cent	Per cent	Per cent	Per cent
None.....	18.1	12.5	8.1	12.9
1 Minute.....	11.2	8.3	5.3	8.3
5 Minutes.....	8.9	6.2	3.0	6.0
15 Minutes.....	3.8	2.0	1.0	2.3
30 Minutes.....	2.1	1.0	0.5	1.2
60 Minutes.....	1.1	0.3	0.2	0.5
Average.....	7.5	5.0	3.0	

¹ $\frac{1}{2}$ minute is equivalent to approximately 6 carloads per 10-hour day in a 24- to 28-brush washer, 1 minute to approximately 3 carloads, and 1½ minutes to approximately 2 carloads.



FIGURE 1.—Two views of rotary-drum potato washer used in experiments.

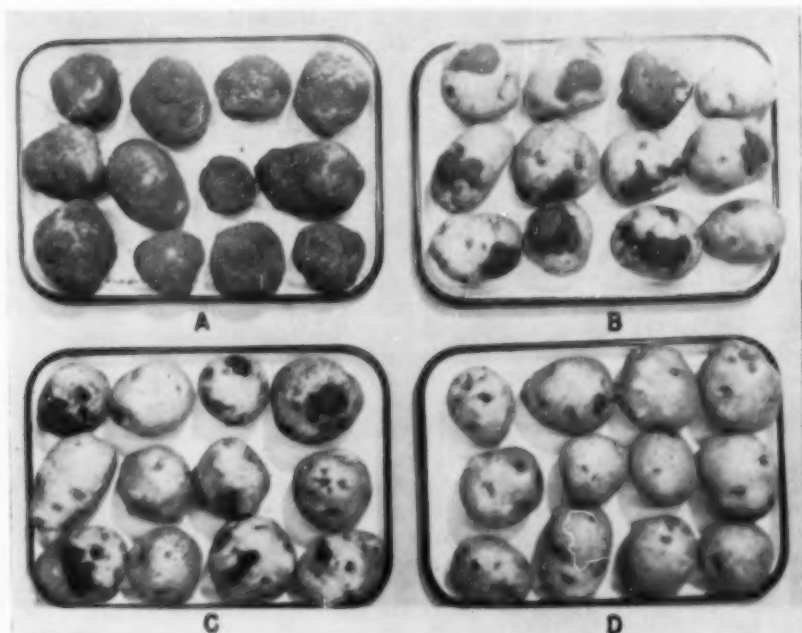


FIGURE 2.—Soil remaining on potatoes: A, not soaked or washed; B, not soaked but washed $\frac{1}{2}$ minute; C, presoaked 5 minutes, washed $\frac{1}{2}$ minute; D, presoaked 60 minutes, washed $\frac{1}{2}$ minute.

Bruising or keeping quality of Triumph potatoes was not affected by length of soaking period.

Since presoaking, especially for long periods, was very effective in facilitating washing, the possibility of wetting down a whole bin of potatoes a day ahead of washing was investigated. This procedure would be practical when potatoes are flumed from the bins. To obtain experimental evaluation of this method, potatoes were immersed in water for 1 minute and kept wet for 24 hours by covering them with wet sacks and holding them in a high humidity room before they were washed in a brush washer. After washing, only 1.9 per cent of the surface of the potatoes previously kept wet for 24 hours was covered with soil, in contrast with 9.7 per cent of that of untreated potatoes. This was, therefore, an effective method of increasing the efficiency of washing. At least one storage house operator in the Red River Valley obtained good results during the 1951-1952 season by wetting down his bins with a fire hose a day before washing, making sure that all the potatoes became thoroughly wet.

Effect of Length of Time in Brush Washer

Increasing the length of time in the brush washer increased the efficiency of washing (Table 1). This fact is of limited value, however,

as the efficiency of washing could be increased only by washing fewer potatoes or installing a larger washer.

Effect of Warming Water and Adding a Detergent

Soaking potatoes in warm water, particularly with a detergent added, increased the efficiency of washing (Table 2) but not sufficiently to be of practical value.

Effect of Drying Adhering Soil

In order to determine the effect of drying the adhering soil before washing, a lot of potatoes was washed directly out of a bin and a comparable lot was held 3 days at 58° F. and 50 per cent relative humidity prior to washing. Under these conditions, the adhering soil dried and started to crack. After washing, only 1.1 per cent of the surface of the tubers dried for 3 days before washing was covered with soil, in contrast with 9.7 per cent of the surface of those washed immediately after removal from the bin. These results are in agreement with the experience of commercial operators who have found that, as the season progressed and the soil on the potatoes became dry, washing became easier.

Effectiveness of a Rotary-drum Washer

Drum washers are sometimes used for presoaking prior to washing in brush washers. The potatoes remained in the rotary-drum washer, used in these tests for 3.7 minutes, as shown in figure 1. A comparison was made between soaking in the drum washer and soaking in a tank for 3.7 minutes (the same length of time the potatoes were in the drum washer) and for 7.4 minutes. After the potatoes were run through the soak tank or the drum washer, they were run through a brush washer. As was expected, the 7.4-minute soak period in a tank was considerably more effective in facilitating soil removal than the 3.7-minute soak period. The results with the drum washer, in general, were intermediate between the results from soaking in a tank for 3.7 and 7.4 minutes.

Effect of Washing Equipment on Appearance and Injury of Potatoes

To determine the influence of washing on injury and removal of sclerotia of *Rhizoctonia*, four 50-pound lots of Red Pontiac and of Irish Cobbler potatoes from each of the treatments indicated in table 3 were inspected after holding 7 days at 40° F. and 80 per cent relative humidity followed by 5 days at 70° and 38 per cent relative humidity. The number of *Rhizoctonia* sclerotia was reduced by washing in the drum washer, and the appearance of the potatoes was improved.

Both bruising and pitting were increased by washing Irish Cobbler potatoes, particularly when both the drum and the brush washer were used (Table 3). It should be pointed out that these potatoes were relatively turgid as they were freshly harvested and were fairly free from dirt. Potatoes in this lot seemed to be especially susceptible to injury, since such severe injury has not been observed in other potatoes.

No important effect of the various treatments on bruising of Red Pontiac potatoes was observed, but slight pitting occurred on potatoes washed in the drum washer alone or in the drum washer followed by the brush washer.

These results show that washing should not be more than necessary to do an adequate cleaning job, particularly with potatoes subject to injury.

TABLE 2.—*Relation of soil remaining to water temperature and presence of a detergent during soaking.*

(Soaked 5 minutes followed by washing in a brush washer)

Temperature (°F)	Soaking Medium	Surface Area Covered with Soil ¹
		Per cent
40	Water	6.5
	Water + detergent ²	8.6
110	Water	4.7
	Water + detergent ²	3.9

¹Difference required for significance at 5 per cent point: 1.8.²Lakesal laboratory glass cleaner.TABLE 3.—*Effect of washing equipment on Irish Cobbler and Red Pontiac potatoes.*

Method of Washing	Irish Cobbler		Red Pontiac	
	Bruising Index	Pitting ¹ (Per cent)	Bruising Index	Pitting ¹ (Per cent)
None (Check)	1.4	0	2.9	0
Drum Washer only	4.1	11.4	2.0	10.6
Brush Washer only (1½ Minutes)	8.8	4.0	2.2	0.5
Drum Washer Plus Brush Washer	19.1	100.0	3.6	18.7

¹Pitting slight to severe on Irish Cobbler tubers washed with drum washer plus brush washer and slight in other cases. Lenticel infection was included with the mechanical pitting.

SUMMARY

Presoaking was the most effective means of facilitating soil removal. This can be accomplished either in a soak tank or by wetting down the potatoes in a bin 1 day before washing.

Increased efficiency of washing was also obtained by increasing the length of time in the washer and drying the adhering soil before washing. A drum washer was only slightly more effective than a soak tank when the same time interval was used for both.

Potatoes susceptible to injury were damaged by too rigid a washing process.

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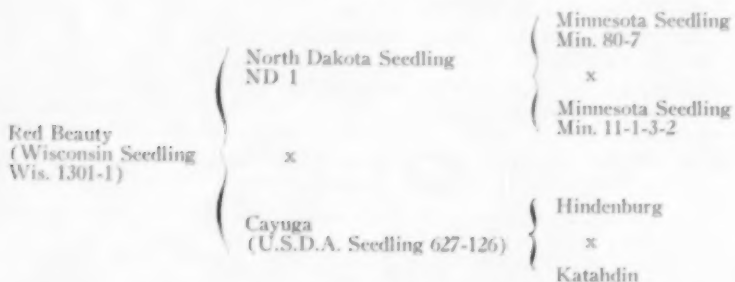
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RED BEAUTY:¹ A NEW BRIGHT-RED MEDIUM-MATURING VARIETY OF POTATO, RESISTANT TO *VERTICILLIUM* WILT

G. H. RIEMAN² AND J. H. SCHULTZ³

The Agricultural Experiment Station of the University of Wisconsin and the Agricultural Experiment Station of the North Dakota Agricultural College released a new variety of potato named Red Beauty. (Figure 1)

PEDIGREE OF RED BEAUTY



The original cross from which Red Beauty was derived was made in the greenhouse at the North Dakota Agricultural College in 1946. It was received at Wisconsin from North Dakota in 1948 in an exchange of some unselected greenhouse-grown seedling tubers between the two agricultural experiment stations. Red Beauty was first selected in a breeding field at Rhinelander, Wisconsin during the fall of 1948. It has been under observation and trial for a period of seven years. Red Beauty has been the most promising red selection in the potato breeding programs carried forward in Wisconsin.

DESCRIPTION AND EVALUATION

Red Beauty is a medium-maturing variety possessing average yielding ability. It is especially adapted to sandy soils. Its oblong tubers have a remarkable bright red skin color which tends to persist for several months in storage. The importance of red-skinned potatoes has increased in the middle west each year during the past decade. It is generally recognized that the red-skinned varieties now commonly grown are frequently inferior to white-skinned varieties in table quality, appearance and adaptability. For this reason, growers are continually searching for more suitable red-skinned varieties. Red Beauty appears to have a more desirable red color than the three leading varieties — Red Pontiac, Triumph and Red Warba. Its tubers are often smoother and have a more attractive shape than any

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Paper No. 584 from the Department of Genetics, University of Wis.

Mr. Melvin Rominsky, Seedsman at Starks Farms, Inc., Rhinelander, Wis., has taken a prominent part in the development of this new variety.

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³ Professor of Horticulture, North Dakota Agricultural College, State College Station, Fargo, N. D.



FIGURE 1.—A typical Red Beauty tuber.

varieties now in commercial production. The eyes are shallow and sparse in number. The new variety has a tendency to develop harvest cracks during certain seasons in a manner similar to the standard Triumph. Its tubers have exceptionally white flesh color. In cooking quality tests, it has rated superior to Red Pontiac and equal to Triumph and Red Warba. Red Beauty retains its good tuber type when grown in heavy clay soil in North Dakota. (Table 1.)

TABLE 1.—Yield per acre and percentage of U. S. No. 1 tubers and total solids content of Red Beauty and Katahdin varieties in North Central Regional Trials, 1953.

Location	Red Beauty			Katahdin		
	Yield per Acre U.S. No. 1		Total Solids	Yield per Acre U.S. No. 1		Total Solids
	Bus.	Per cent	Per cent	Bus.	Per cent	Per cent
Kansas.....	145	56	158	68
North Dakota.....	167	90	18.2	130	95	17.9
South Dakota.....	143	78	16.7	167	72	15.8
Iowa.....	221	73	17.4	238	76	17.7
Wisconsin.....	427	91	20.2	364	94	20.9
Indiana.....	163	42	17.7	172	35	17.7
Michigan.....	273	89	19.4	404	94	19.4
Nebraska (Mitchell).....	335	77	20.7	316	79	19.9
Nebraska (Cozad).....	238	79	14.2	163	81	14.7
Average*	237	75	18.1	237	77	18.0

*No significant differences between the two varieties in yields of U. S. No. 1 potatoes or in total solids content were observed at the nine locations.

The Red Beauty plants have an upright habit of growth. The plant size is similar to Katahdin. It sets its tubers deep in the soil and well under the plant on short rhizomes. Sun greening seldom occurs. Only trace amounts of field frost injury were observed in Red Beauty in several trials where the standard varieties Katahdin and Chippewa were severely damaged by field frost. The growth habit of the new variety is adapted to modern potato growing practices.

Red Beauty is similar to Red Pontiac and Triumph in its susceptibility to rugose mosaic caused by the synergistic interaction between viruses X and Y. It is also susceptible to common scab. The variety has shown tolerance to purple top wilt in field trials in Northern Wisconsin. This disease, incited by the aster-yellows virus, has been extremely destructive and widely prevalent for many years in the northern potato growing areas of the nation. Most of the standard varieties, and especially Red Pontiac, are susceptible to purple top wilt. Red Beauty has shown resistance to *Verticillium* wilt in field tests in Northern Wisconsin. This old soil-borne potato disease has become common and increasingly severe on many standard varieties in various parts of the United States and Canada. Strains of the causal organism differing in pathogenicity are now recognized.

SUMMARY OF RED BEAUTY CHARACTERISTICS

1. Mid-season maturity
2. Average yielding ability
3. Adapted to sandy soils
4. Attractive bright red skin color
5. Bright red color persists in storage
6. Unusually smooth tuber shape
7. Some tendency to harvest cracks
8. Exceptionally white flesh color
9. Specific gravity equal or superior to the three leading red-skinned varieties now grown
10. Plants medium size, upright habit
11. Tubers set deep in soil on short rhizomes
12. Susceptible to rugose mosaic and common scab diseases
13. Tolerant to purple top wilt
14. Resistant to *Verticillium* wilt.

NEWS AND REVIEWS

POTATO HANDBOOK ANNOUNCED

A brand new official publication, the 1956 edition of The POTATO HANDBOOK will be ready for release by The Potato Association of America about the first week in December. This valuable book will contain official crop information from every state on seed certification, storage, disease control as well as a complete buyers' guide, listings of state potato associations and many valuable ideas for growers and buyers alike.

This issue will feature seed potato certification and will list all of the varieties certified in the United States and Canada. It will also contain feature articles on potato varieties and insect and disease control by eminent authorities.

The Potato Handbook is not to be confused with the American Potato Yearbook which is published by a private company in no way connected with the Potato Association of America and was previously distributed through the Association.

One free copy will be sent to all regular members. Anyone desiring more copies of the Potato Handbook may secure them for \$2.00 each. 26 to 50 copies \$1.50 and 51 or more \$1.00 each. Order from The Potato Association of America, Nichol Avenue, New Brunswick, N. J.

NEW VARIETIES IN PRACTICE

In "The Windmill" No. 12 of December 1953 a brief description was given of the new potato varieties which were placed on the Netherlands Descriptive List of Varieties of Field Crops for the first time in 1954. Similarly the last number of "The Dutch Potato" summarized the chief characteristics of those potato varieties which were added to this list in 1955.

The reader will doubtless be aware that a variety is only included in the list after a number of years of thorough testing and assessment of its properties and qualities, during which period no seed potatoes may be made available to agricultural practice in general.

Inclusion in the list of varieties entails that the seed potatoes may be freely marketed and, needless to say, the practical side itself forms the final opinion. It is worth examining here how the varieties placed on the list of varieties in the last five years fared.

Starting with the year 1950, we note that, of the 5 varieties of that year, 2 have since been removed from the list again. These are Thorma and Noordstar; the former proved unsatisfactory owing to its great susceptibility to *Phytophthora* on the leaf, whilst the latter could find no acceptance with seed potato growers, owing to difficulties in roguing for mosaic. As from the beginning of 1955 both varieties have been deleted from the Netherlands List of Varieties.

Agriculture's interest in Gineke is clearly increasing. The varietal

statistics show that whereas Gineke was (naturally) only sporadically cultivated in 1950 and 1951, it occupied in 1952, 1953 and 1954 $\frac{1}{2}$, 1, and $1\frac{1}{2}$ per cent respectively of the total acreage planted with potatoes in Holland.

Gineke is a medium late, red skinned potato. The tubers are light-yellow fleshed, moderately deep eyed, and oval-round in shape. The variety is little susceptible to *Phytophthora* of the leaf and of the tuber, to spraying and to other internal tuber diseases, and is immune from virus A mosaic. A further important point is its good resistance to drought.

Urgenta was placed on the list in 1950 in the "Varieties destined only for export" section, but in 1953 the growing restrictions inherent therein were lifted by normal inclusion in the list of varieties. Naturally this fairly recent withdrawal of the restrictive measures does not yet find expression in the statistical data, but the fact in itself indicates that the variety has not proved disappointing. Urgenta is medium early, with light-red skin and light-yellow flesh. The tubers are well formed, large and oval-long, with shallow eyes. Great susceptibility to common scab disease, but on the other hand only slight susceptibility to *Phytophthora* of the leaf and of the tuber.

The last addition in 1950 to be mentioned is Ari, which was included in the "Varieties destined only for export" section. This variety gives a good to very good yield of large, flat oval-round, fairly shallow eyed, light-yellow fleshed tubers. Moderately susceptible to *Phytophthora* of the leaf, but little susceptible to *Phytophthora* in the tuber. Ari has attracted interest in several countries, partly as a result of its good resistance to drought.

The two new varieties placed on the list in 1951 have done well up to now.

The very early variety Sirtema has this year been placed in the category of varieties suitable for general cultivation. As is the case with most early varieties, Sirtema is very susceptible to *Phytophthora* of the leaf, but somewhat less so in the tuber. The variety is characterized by light-yellow fleshed, well formed, large oval-round tubers with fairly shallow eyes. The yield is very good, whether it is lifted very early or when ripe.

Sientje, a medium early variety, has now been occupying a steady position for 4 years in succession, *viz.* $\frac{1}{2}$ per cent of the total acreage in Holland. Several countries are particularly interested in it. The crop yields a fairly large number of rather big, long, pointed, sometimes a little misshapen, yellowish white fleshed tubers, which are easy to lift. Moderately susceptible to *Phytophthora* of the leaf and tuber and immune from virus A mosaic and wart disease.

Prudal, placed on the list of varieties in 1952, is a medium early variety with a good yield of nicely formed oval-round, yellow fleshed tubers with shallow eyes. Fairly large number of tubers per plant with uniform grading. Susceptibility to *Phytophthora* is moderate in the leaf, and slight in the tuber. Interest in the variety is still very limited.

Needless to say, little can be said as yet of the cultivation in practice of those varieties placed on the list of varieties in 1953. We shall therefore confine ourselves to a short description of the most important properties of these varieties.

Barima (1953) ripens very early and gives very high yields of light-yellow fleshed tubers of fairly good shape. Very susceptible to *Phytophthora*.

Prinslander (1953) is a medium early, very good yielding variety with oval, well formed, light-yellow fleshed, shallow eyed tubers, which sometimes become very large. Resists drought fairly well. Rather susceptible to *Phytophthora*; immune from wart disease.

Irene (1953) is a medium late red-skinned potato with nicely formed, oval-round shallow eyed, yellow fleshed tubers. Fairly good yield; very good grading. Little susceptible to *Phytophthora*.

Pimpernel (1953) a late variety with a good yield of nicely formed, oval-round, shallow eyed, yellow fleshed tubers with dark-red skin. Very little susceptible to *Phytophthora* and little sensitive to leaf roll.

Froma (1953) is medium early and gives a good to very good yield of oval-round tubers with fairly shallow eyes and light-yellow flesh. In the leaf this variety is susceptible to *Phytophthora*, but in the tuber only slightly so. Its susceptibility to leaf roll is also fairly slight.

—Reprinted from THE WINDMILL, April, 1955

DUTCH POTATO ATLAS PUBLISHED

In September of this year a potato atlas, embodying the Dutch assortment of varieties, will be published by Veenman & Zonen, Wageningen.

For each variety (46 varieties in all) a four-color illustration is given of the tuber, flesh color, sprout in light, leaf and flower, accompanied by a detailed description of the properties, which will be available in English, French, German or Dutch.

The loose-leaf system used means that the atlas is always up to date.

The publication is edited by Dr. J. A. Hogen Esch, Dr. F. E. Nijdam and Dr. H. Siebeneick.

The price will be 30 Dutch guilders per copy and per language.

Orders, stating the number of copies and the language required, may be sent to:

The Publishers of "The Windmill," Zwarteweg 75, The Hague, Holland.

RESULTS OF 1954 FUNGICIDE TESTS

"Results of 1954 Fungicide Tests" reprinted from a series of articles appearing in *Agricultural Chemicals*, April through June, may be purchased in bound and covered form for \$1.00 per copy by sending orders with remittance to Dr. D. A. Roberts, Department of Plant Pathology, College of Agriculture, Cornell University, Ithaca, New York. The publication of these results is under the sponsorship of the American Phytopathological Society. It is a continuation of the publication of results formerly provided through a Supplement of the Plant Disease Reporter, Plant Disease Epidemics and Identification Section, U. S. Department of Agriculture.

The Temporary Advisory Committee on Collecting and Disseminating

Data on New Fungicide Tests of the American Phytopathological Society arranged for the recent publication of data and the continuation of a program for annual publications of Fungicide Test Results in the future. Dr. D. A. Roberts, Department of Plant Pathology, Cornell University, Ithaca, New York, will be in charge of this project during the current year.

UNITED PUBLISHES NEW EDITION OF INDUSTRY REFERENCE SOURCES

"Where to Find the Answers to Questions about Fresh Fruit and Vegetable Marketing," a 14 page report listing sources of information on a wide variety of subjects dealing with the complex ramifications of the produce industry, has been published by the United Fresh Fruit & Vegetable Association. This is the third revised edition of the report, which has been greatly expanded.

Among the subjects covered is a list of information sources on radiation and the contributions of atomic energy to agriculture. These sources include reports of hearings before Congressional atomic energy committees, reports of scientific experiments on the progress of food preservation by radiation, progress of experiments with potatoes and other fresh commodities and much other information on this vital subject.

Other sections include sources on such subjects as buying habits; shopping habits and preferences of consumers; food store operation; grocery store facts; modern wholesaling methods; refrigeration; merchandising and marketing practices; nutritional information; operating ratios; price spreads; waste and loss appraisals; and labor relations. Sources of information on containers, packaging studies, harvesting and planting dates, shipping deal summaries, directories and trade associations are listed. There is also a section on major sources of information on each of the main fresh commodities.

The report was compiled by R. A. Seelig, the United's director of information, from materials in the United's library, from Government agencies and many other reference sources. It is available for \$2 a copy from the United Fresh Fruit & Vegetable Association, 777 14th Street N. W., Washington 5, D. C.

COOKING QUALITY OF POTATOES CAN BE PREDICTED. USDA RESEARCH SHOWS

Consumers in the future may be able to buy the potatoes that will be best for boiling, or for baking, or frying, or chipping by reading a label on the sack. Tests by research scientists in the U. S. Department of Agriculture indicate information could be obtained that would enable producers and distributors to label their potatoes, designating on the label the cooking method that would give the best quality product.

Dry matter, alcohol insoluble solids, and starch were all found to be

good measures of cooking quality, but specific gravity was found to be the simplest and most practical measure for predicting the quality of potatoes when cooked.

Different varieties of potatoes, each from several locations, were obtained by the scientists and were stored under different conditions. The cooking quality for boiling, mashing, and baking was determined, and results were correlated with the composition of the raw potatoes. Samples of potatoes grown in three different years were tested.

The eating quality of the potatoes varied considerably. Differences in the ratings of potatoes of the same variety grown in different locations and in succeeding years were as great as the differences among varieties. Katahdins grown in one State were among the mealiest, whereas samples of the same variety grown in another State were among the least mealy.

Mealiness is usually desired in boiled, mashed, and baked potatoes, but some of the mealiest potatoes slough badly (outer layer breaks off) and do not hold their shape well when boiled. In the study it was found that mealiness was influenced as much by location as by variety.

In general, the method of cooking made little difference in the mealiness, dryness, and flavor — a potato that was dry and mealy when boiled was also dry and mealy when mashed or baked. In color, however, the differences were more pronounced. The color of mashed or baked potatoes was likely to be more attractive than the color of boiled potatoes; in some samplings, ricing and blending improved the color of potatoes that had been boiled.

Length of storage affects the eating quality of cooked potatoes. The longer potatoes are stored, the less mealy and the sogger they become. On the other hand, sloughing is not as great in stored potatoes.

A copy of the report on this study, "Cooking Quality and Compositional Factors of Potatoes of Different Varieties from Several Commercial Locations," Technical Bulletin No. 1106, may be obtained from the Superintendent of Documents, Government Printing Office, Washington 25, D. C., at 35 cents a copy.

JAYFLO IRRIGATION PUMP FOR TRACTOR OPERATION

A new tractor driven irrigation pump, the Jayflo "25," has been added to the line of Jayflo Products Company of Minneapolis. The pump uses direct drive from the power take off shaft of any farm tractor. It features all-aluminum construction of pump housing and impeller which prevents efficiency-stealing rust and scale formations. Pumping capacities range from 435 GPM at 40 PSI to 265 GPM at 70 PSI with suction lift not exceeding 20 feet.

A step-up gearbox ahead of the pump raises the 550 RPM input speed from the tractor to an impeller speed of 2380 RPM. Construction features include stainless steel shaft sleeve and wear ring to increase pump life and resist corrosion; face type shaft seal which never requires adjustment or tightening; and large, helical cut hardened gears mounted on Timken roller bearings and enclosed in an oil filled housing.

The Jayflo "25" is available with hitch and trailer with 4.00 x 8. tires as shown, or on skid mount.

Jayflo also manufactures the Jayflo "20" and Jayflo "10," portable self powered pumps. For complete information write: Jayflo Products Company, 5145 Idaho Ave. North, Minneapolis 22, Minn. Mention this publication.



TRACTOR-MOUNTED COMPRESSOR OFFERED BY WORTHINGTON MOWER

The Worthington Mower Company of Stroudsburg, Pa., pioneer manufacturer of gang mowers and tractors for large-area grass maintenance, has just introduced a new and novel portable air compressor that can be attached to the rear power-take-off of all makes of tractors quickly and easily.

Known as the Worthington-Mobilco Air Compressor, the new unit will prove to be a valuable, low-cost compressed air supply for farmers. With this power-take-off compressor, users will be able to power grease tractors and other farm allied equipment, pump gasoline, maintain correct tire pressure in the field, spray paint inside or outside buildings, as well as spray fruit trees, vegetables and shrubs.

The unit can be attached to a tractor power-take-off in a matter of minutes. The compressor shaft sleeve slips over the splined take-off shaft and the single sleeve thumb screw is secured. The compressor frame rests against the frame of the tractor when the power-take-off shaft is started.

The new compressor is sturdily built. Close grained, cast iron is used for the frame and cylinder. The piston is of steel having two cast iron rings and the connecting rod and crankshaft is of rugged, forged steel. Ball bearings are used throughout.

The compressor has a capacity of 2 c.f.m. at 400 rpm. with pressures up to 120 P.S.I. A built-in relief valve opens when line pressure at accessory is closed thus protecting the unit. A specially-designed pressure chamber in the line provides a smooth, non-pulsating supply of compressed air.

By means of a change-over piston and cylinder kit, the compressor can be converted quickly into a pump for boom spraying.

For complete information on this portable compressor, write directly to Worthington Mower Company, Stroudsburg, Pa. Mention this publication.



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